ORIE 4741: Learning with Big Messy Data

Exploratory Data Analysis

Professor Udell
Operations Research and Information Engineering
Cornell

August 31, 2021
Announcements

▶ If you’re taking lecture async: remember to submit participation post after each class!
▶ Otherwise, register your iClicker.
▶ Sections start next week. They are optional, attend any one you prefer. Only two (on Tuesday and Wednesday) will be live.
▶ Office hours: Zoom links or rooms and times are posted on course website.
▶ Gradescope is open for submission of hw0, due Thursday 9:30am.
▶ First quiz this week! It should occupy about 20 minutes; you’ll have up to half an hour to complete it. Start it anytime between 10am Friday and noon Saturday.
Questions from zulip

- enrollment: yes, we expect you’ll get in!
- protocol:
  - use the right stream (eg, general, homework, project, ...)
    and a good subject line
  - search for your question before posting new question
Our programming language policy

- we’ll do demos and provide homework starter code in python
- you’re welcome to use any language you like (that your TAs can read) for homework or project
- TAs will only support python
 Topics to review

We will cover (most of) these in section, too:

▶ Linear algebra: invertible matrices, rank, norm, basic matrix identities. When is a matrix invertible?
▶ QR factorization
▶ Gradients (multivariate derivative)
▶ Projections
▶ SVD
▶ Maximum likelihood estimation
▶ Union bound
▶ Computational complexity
Why look at the data?

- detect errors in data
- check assumptions
- select appropriate models
- understand relationships among the features
- understand relationships between features and labels
How to look at the data?

- inspect raw data
- summary statistics
- visualize
American community survey

2013 ACS:

- 3M respondents, 87 economic/demographic survey questions
  - income
  - cost of utilities (water, gas, electric)
  - weeks worked per year
  - hours worked per week
  - home ownership
  - looking for work
  - use foodstamps
  - education level
  - state of residence
  - ...

- 1/3 of responses missing

find it at https://people.orie.cornell.edu/mru8/orie4741/data/acs_2013.csv
How do computers work?

on a laptop:

- hard disk: usually $\leq 500$ GB
- memory (RAM): usually $\leq 16$ GB
- many programs (e.g., Excel): substantially more limited
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don’t load a giant file into memory.
your computer will crash.
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on a laptop:

► hard disk: usually $\leq 500$ GB
► memory (RAM): usually $\leq 16$ GB
► many programs (e.g., Excel): substantially more limited

don’t load a giant file into memory.
your computer will crash.

how big is ACS data?
3M respondents $\times$ 100 questions $= 300M$ numbers $\approx 300$MB
Inspect raw data

solution for large files: technology from the 70s!

bash shell:

▶ “how big are these files?”: ls -lh
▶ “show me some lines from the file”: head, tail, less
▶ “how many lines are in the file?”: wc -l
<table>
<thead>
<tr>
<th>Variable</th>
<th>Description</th>
<th>Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>HHTYPE</td>
<td>household type</td>
<td>categorical</td>
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<td>STATEICP</td>
<td>state</td>
<td>categorical</td>
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<td>OWNERSHP</td>
<td>own home</td>
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<td>household income</td>
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<td>monthly electricity bill</td>
<td>real</td>
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<td>monthly water bill</td>
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<td>have health insurance</td>
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<td>currently in school</td>
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<tr>
<td>EDUC</td>
<td>highest level of education</td>
<td>ordinal</td>
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<td>highest grade level attained</td>
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<td>MIGRATE1</td>
<td>migration status</td>
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Python and Jupyter

- Python is a programming language: it parses human-readable code to machine-readable code, executes it, returns the answer
- Jupyter is a protocol for interacting with a programming language.
- Jupyter stores inputs and outputs as .ipynb files.
- Jupyter notebooks display inputs and outputs in a browser
- Google Colab is an interface to a webserver running Python
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How to access?

- Install Python with Anaconda distribution (versions 3.7 or 3.8 are fine).
- Use Google Colab.
Summary statistics

univariate

▶ mean, median, mode
▶ max, min, range
▶ variance
▶ ...

explore via Python + Jupyter notebook

https://github.com/ORIE4741/demos/blob/master/eda.ipynb
Summary statistics

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explore via Python + Jupyter notebook

https://github.com/ORIE4741/demos/blob/master/eda.ipynb

multi- (but usually just bi-) variate

► correlation, covariance
► …
## The perils of summary statistics

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same mean, variance, correlation, line of best fit...
The perils of summary statistics
The perils of summary statistics: modern update

https://www.autodeskresearch.com/publications/samestats
What to visualize?

- examples across all features (usually not)
- plot features across all examples (much more common)
Best practices

- Always label your axes.
- Ensure all marks on plot are meaningful.
- Beware of pie charts; bar charts are often easier to read.
- Beware of line plots; if your data is not continuous, try scatter plot instead.
- Consider the scale of your axes. Log scale or not?
- Consider which curves to plot on same axes. Make comparisons easy!
Beware of bad data

Label: Number of Days Physical Health Not Good
Section Name: Healthy Days — Health Related Quality of Life
Core Section Number: 2
Question Number: 1
Column: 91-92
Type of Variable: Num
SAS Variable Name: PHYSHLTH
Question Prologue:
Question: Now thinking about your physical health, which includes physical health, vitality, and all the days you didn’t feel well in the past 30 days was your physical health not good?

<table>
<thead>
<tr>
<th>Value</th>
<th>Value Label</th>
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<tbody>
<tr>
<td>1 - 30</td>
<td>Number of days</td>
</tr>
<tr>
<td>88</td>
<td>None</td>
</tr>
<tr>
<td>77</td>
<td>Don’t know/Not sure</td>
</tr>
</tbody>
</table>
Take away

- always look at (some of) your data
- decide what question you want to answer
Questions?

https://docs.google.com/spreadsheets/d/1vLbwi0WClOoU6cU_r0RHAwY7C0fDZ1F8Yq09pqYYuk